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The Role of Research and Development on Safety Regulation

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16. Abstract

A review of regulatory actions taken by the Federal Aviation Administration (FAA) over approximately the past thirty years was made to identify which of these actions were preceded by, or triggered by research and development (R&D) programs. The focus of this analysis was limited to those actions and R&D that pertained to aircraft safety. Research was frequently requested to be performed by the industry elements themselves, namely the engine and aircraft manufacturers, independent research organizations, or by academia. As the FAA experience with the operational fleets grew, some research was accomplished by the internal FAA and governmental organizations, such as the Civil Aeromedical Institute or the Technical Center, and the National Aeronautics and Space Administration.

The review revealed that the rulemaking actions were supported quite frequently by research. While it is true that major accidents brought the attention to technology unknowns, and the subsequent rulemaking to prevent the problem appeared to be moving too slowly to provide solutions to the need, the review showed many risks have been reduced, (cabin fires, inadvertent collision with terrain, faster evacuation, to name a few) through the performance of research.

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LIST OF ABBREVIATIONS AND SYMBOLS

AC	Advisory Circular
AD	Airworthiness Directive
AMA	American Medical Association
ANPRM	Advanced Notice of Proposed Rulemaking
ATC	Air Traffic Control
CAMI	The Civil Aeromedical Institute
CFIT	Controlled Flight Into Terrain
CID	Controlled Impact Demonstration
CVR	Cockpit Voice Recorder
DOT	Department of Transportation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDR	Flight Data Recorder
GPWS	Ground Proximity Warning System
MLS	Microwave Landing System
MSD	Multi-Site Damage
NACA	National Advisory Committee for Aeronautics
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NHSTA	National Highway Transportation Safety Administration
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board
PBE	Protective Breathing Equipment
TSO	Technical Standard Order
PMI	Principal Maintenance Inspector
R&D	Research and Development
SAFER	Special Aviation Fire and Explosion Reduction Advisory Committee
TCAS	Traffic Alert and Collision Avoidance System
TWA	TransWorld Airlines
VNTSC	Volpe National Transportation Systems Center
WFD	Widespread Fatigue Damage

EXECUTIVE SUMMARY

A review of regulatory actions taken by the Federal Aviation Administration (FAA) over approximately the past thirty years was made to identify which of these actions were preceded by, or triggered by research and development (R&D) programs. The focus of this analysis was limited to those actions and R&D that pertained to aircraft safety. Research was frequently requested to be performed by the industry elements themselves, namely the engine and aircraft manufacturers, independent research organizations, or by academia. As the FAA experience with the operational fleets grew, some research was accomplished by the internal FAA and governmental organizations, such as the Civil Aeromedical Institute or the Technical Center, and the National Aeronautics and Space Administration.

The review revealed that the rulemaking actions were supported quite frequently by research. While it is true that major accidents brought the attention to technology unknowns, and the subsequent rulemaking to prevent the problem appeared to be moving too slowly to provide solutions to the need, the review showed many risks have been reduced, (cabin fires, inadvertent collision with terrain, faster evacuation, to name a few) through the performance of research.

1. BACKGROUND.

Commercial air transportation in the United States underwent an almost explosive expansion and development during the period from the late 1950s through 1990. In the first decade of this period, 26 new transport aircraft were introduced that virtually eliminated passenger transport by the existing piston driven airline fleet.

Just prior to this huge influx of new aircraft, the Federal Aviation Agency evolved from the existing Civil Aviation Authority in 1958. The Federal Aviation Agency was later absorbed into the Department of Transportation (DOT) as the Federal Aviation Administration (FAA). The charter of the FAA was unchanged by the joining with the DOT. It was charged by the Federal Aviation Act of 1958 with encouraging the development of civil aeronautics and air commerce in the U.S. and abroad. The FAA also was faced with the parallel and equally important task of assuring safe flight for the flying public.

With the expansion created by the advent of the turbine powered aircraft, business travel became the major element of the increase in traffic, whereas it had previously been patronized primarily by the affluent. Businesses found the time saved was worth the price—and with the increased patronage, the airlines could make the cost even more affordable—a case of demand driving the price down because of the huge increase in volume.

With the introduction of the Boeing 747 wide-bodied aircraft, (the McDonnell-Douglas DC-10, and the Lockheed L1011 followed shortly) in the early 1970s, the availability of reasonable seat cost opened the way to an upsurge in pleasure travel.

Of course, the unsettled international situations and several fuel crises tended to level out this trend. Through it all however, the FAA was still charged with maintaining the highest degree of safe air travel. Over the period 1960 through 1990, this was accomplished in steadily improving fashion. The actual number of accidents showed an increase in the late 1960s and early 1970s, but the volume of traffic, when factored in, showed that the accidents per mile or per number of flights was really decreasing.

2. PURPOSE.

The purpose of this effort is to assess the effects that FAA research and development have had on regulatory actions affecting aircraft and passenger/crew safety. While the impact of the research on the generation of improvements is focused, an equally important aspect is the research that validated or supported the adequacy of safety regulations already in effect.

3. APPROACH.

The following are initial attempts to connect the Notice of Proposed Rulemaking (NPRM) and other data to the benefits of research and development. The individual sections generally parallel the research and development program plan for aircraft safety that the FAA follows, with a few deviations. FAA research treats structural work separately according to Crashworthiness,

Airworthiness, and Aging Aircraft. Although Aging Aircraft research was not a part of the overall plan until late 1989, the magnitude of the problem and the potential for fleet-wide difficulties generated a large effort. Because of the relative newness of the research work, few regulatory actions, other that a wide dissemination of Airworthiness Directives, have been formulated.

The amount of information that was found that addresses evacuation (although not a specific section in the FAA's Aircraft Safety Research Program prior to 1990) warranted a separate section for that subject.

Difficulty was encountered in establishing a connection between research funding and research tasks that produced meaningful results. Data defining expenditures toward a specific product before the early 1980s was very sparse. The funding data for the later years also presented problems in that different sources gave significantly varying amounts, with no way of establishing the true level of funding. Because of these problems, it is felt best to present only trends.

4. DATA SOURCES.

A review and analysis of all NPRMs, Advanced Notices of Proposed Rulemaking (ANPRM)s, Modifications, Withdrawals and Final Rules was undertaken for the period 1965 through the present. Each item was classified as to which subject heading of the aviation safety research program plan it addressed. These were then addressed chronologically to show the progression of developments for each area.

5. INFORMATION SCREENING AND SELECTION RATIONALE.

For each of the items located and reviewed above, attention was paid to whether research and development efforts were associated with the decision making processes. That is, whether the work was as a result of independent industry action, requested of industry or other government agencies by the FAA, or as the result of proposed regulatory action by the FAA.

The most important factor considered in this area was whether research and development preceded and was directed toward the regulatory action. In some instances, references to past research were cited as supporting the intent to regulate; these were of equal importance.

6. TIME PERIOD SELECTION RATIONALE.

A review and analysis of the data sources listed above over the time period from the mid-1960s to the present was conducted. Prior to the mid-1970 time period, the FAA, possibly because of its inception in the late 1950s, was not very active in research and development, with most of the safety improvements emanating from the industry itself. In the mid-1970s however, a noticeable change was seen. The formation of the Special Aviation Fire and Explosion Reduction (SAFER) Committee was a significant event that brought the governmental and industry research personnel into the forefront. Many of the regulatory proposals cited the results of the research in its area of

interest. Because of this apparent stronger dependence on the research and development results, the mid-1970 time period was selected as the baseline date for the report.

7. FAA RESEARCH AND DEVELOPMENT/REGULATORY PROCESSES.

Aircraft safety research and development within the FAA has been undertaken to support the Agency's Congressionally mandated direction to ensure safe transport for the flying public and secondarily to promote the well-being and advancement of the air transportation system. To meet these two charges, the FAA applies certification standards to both the manufacture of the aircraft, propulsion, and control systems and the rules defining the safe operation of the complete system.

The standards addressing the production of the aircraft are flexible enough to allow application to all models and versions of those models. Infrequently, special provisions are made to these standards to bring a facet of a new aircraft or a modification of an existing aircraft into alignment with the desired level of safety assurance. In the main, however, the standards that are applied to the aircraft itself remain fixed for that particular vehicle.

In the case of the operational limitations, more flexibility is evidenced. As technology developments are brought forth, the improvements in flight control or air traffic procedures are applied across the whole spectrum.

Both the certification and operational processes often are faced with proposed changes and advancements that are not fully addressed by the existing rules. It is at this time that the role of research and development becomes important to the Agency goals; safe flight and industry development.

The research organizations of the FAA, namely the Technical Center and the Civil Aeromedical Institute, respond to these goals primarily through requests from the certification and operational elements of the FAA. Although a large number of requests for research and development do spring from accidents, FAA analyses of future aircraft also generate needs to understand the impact on the technology and whether the current rules are applicable to the new or anticipated situation.

The results of the research that are conducted by the FAA are provided to the certification and operational organizations to support their rulemaking actions. FAA research organizations also enlist the skills and expertise of other Government facilities such as the Department of Defense (Air Force and Navy) and the National Aeronautics and Space Administration (NASA) to have specialized investigations conducted. The FAA research organizations also utilize the abilities of the aviation industry itself to solve some of the problems.

8. THE ROLE OF RESEARCH AND DEVELOPMENT IN AIRCRAFT SAFETY.

In December 1974, a TransWorld Airlines (TWA) Boeing 727, approaching Dulles International Airport, descended too soon and crashed into a mountain near Berryville, Virginia, killing all 92 people aboard.

In March 1977, two Boeing 747's collided on a runway at Tenerife, Canary Islands, under limited visibility. The Pan Am 747 was moving down the runway toward an assigned taxiway. The KLM 747 was waiting at the end of the same runway. The KLM Captain apparently misinterpreted a message from the tower as clearance to take off. The collision killed all aboard the KLM 747 and all but 61 aboard the Pan Am 747. The fatality total was 583. Most of the casualties were caused by the intense fire that engulfed both aircraft.

In July 1982, a Pan Am 727 crashed shortly after takeoff from New Orleans International Airport, killing all 145 aboard and 8 persons on the ground. The NTSB listed the accident's probable cause as the airplane's encounter with microburst-induced windshear.

Today these accidents and the subsequent loss of lives are less likely because of safety improvements brought about by regulations that were supported by FAA research such as installing ground proximity warning systems, use of fire retardant materials in aircraft cabins, cabin improvements for quicker evacuations, implementation of cockpit resource management, and improvements in windshear detection equipment.

There are schools of thought that feel aviation can never be 100 percent safe. Nonetheless the FAA continues to improve its safety record to reach a condition of zero accidents. Though aviation was the safest form of mass transportation 30 years ago, today it is several orders of magnitude safer. In 1965, accidents in which some of the passengers survived, 64 percent of the passengers on board an accident aircraft died. If that same percentage persisted in 1990, 336 persons would have died in survivable accidents. The actual number of deaths was 85, 16 percent rather than 64 percent of the number of passengers on board survivable accidents.

Air transportation is safer today for many reasons, not the least of which is government regulation and the research that supports that regulation. The first goal of a safety regulatory agency is to take every reasonable step to prevent accidents. The second is to ensure that as many people as possible are saved in a survivable accident. The improvements in air travel safety exist today because the FAA has acted on both levels.

9. PREVENTING ACCIDENTS.

Air crews are better trained to handle more sophisticated aircraft in an increasingly complex setting. Pilots are given specialized training for emergency situations such as windshear and icing conditions. Much of this training is accomplished in simulators, which allow pilots to experience conditions that could not have been experienced in training without simulators. In the case of windshear this has made pilots aware of how important it is to avoid windshear if at all possible. Pilots who transition to new aircraft are now required to use the knowledge and skill they learned

in transition training in actual flight time within a short period of time after that training so that they can put into practice and reinforce what they have learned. Pilots now must undergo training in cockpit resource management, that is, in team work in the cockpit so that flight crews work together effectively. This type of flight crew training is especially effective in simulation where emergency conditions as well as routine conditions of actual flight can be duplicated and pilots' and crew can be checked on their abilities to work as a team. Airlines must now schedule flight crews so that an acceptable level of experience is maintained at the flight controls.

Aircraft equipment has been developed and improved to increase the level of safety of each flight. Airplanes are now equipped with ground proximity warning systems to alert the crew when an aircraft is too close to the ground. Doppler and other modern radar, including improved windshear detection equipment, provide information on applicable weather conditions and on other flights. Instrument landing equipment has been improved to aid pilots who must make a landing in low visibility. Traffic Alert and Collision Avoidance System (TCAS) equipment has been installed to alert pilots if they are too close to other airplanes. Security equipment for detecting bombs and weapons has been improved. Cockpit voice and flight data recorders provide data from accidents and incidents that can be analyzed to prevent future accidents.

The safety of passengers during takeoffs, landings, and turbulence has increased by requiring fastened seatbelts at these times and by allowing, but not requiring, the use of child restraints.

Safety of flight in snowstorms has increased by requirements to provide an extra margin of runway for landing in adverse weather and to have a deicing program to prevent taking off with ice on the airplane wings.

The airworthiness of the aircraft has improved through the continual airworthiness review process and issuance of Airworthiness Directives. Changes are continually being proposed to increase safety. Those which meet the test of technical and economical worth, while providing added safety, are applied to aircraft design requirements. Such are the improved resistance to engine rotorburst protection,[1] aircraft and engine control automation,[2] low fuel quantity alerting systems,[3] etc. The aging aircraft program[4] has increased inspections and identified the problems to look for and correct. Engine durability in case of bird ingestion has progressed steadily to withstand such an event.[5]

10. SURVIVING ACCIDENTS.

Many improvements have occurred to increase survivability in airplane accidents. The number of flight attendants has increased and the training of flight attendants in evacuation procedures has improved. Passenger briefings are now conducted to prepare passengers for the event of an emergency. Carryon baggage rules have eliminated clutter that could slow evacuation. Requirements on seat backs have improved access to aisles and to window exits for faster evacuation. Portable megaphones are now required to allow for emergency personnel to communicate with passengers in emergencies. Flotation devices are required for each passenger. Fire-blocking fabrics and panels are now used in the aircraft to reduce fire and toxic gasses, numerous hand-held extinguishers are provided for the cabin crew, and emergency floor lighting

has been installed to assist in aircraft egress. Automatically inflatable and deployable slides are used for quicker and safer evacuation. (In contrast to 1965, adding ropes at window exits was considered a significant improvement.).

11. THE ROLE OF RESEARCH IN SAFETY.

Many rule changes were supported by FAA research but some were not. Some changes that have yet to be accomplished need the research in order to justify how to do them, and this needed research sometimes is exploratory. Historically, the FAA performed only developmental test and evaluation. Although the FAA Act of 1958 authorized research and development by the FAA, such work was usually of the applied research type. Since some of these needed changes involved research of a basic nature because the technical principles were not yet known, the FAA relied on the basic research work done by the industry itself, military organizations, and that of NASA, (once known as National Advisory Committee for Aeronautics (NACA)). More recently however, the Aviation Research Act of 1988,[6,7] among other enactments, opened the scope of the FAA's authority and allowed direct investigation of the needed research principles. The Act and other enactments direct the FAA to undertake research on aircraft structures, human factors, aeromedical research, and computer simulation models of the air traffic control system. There are two research facilities in the FAA that are the primary units to respond to this direction: The Civil Aeromedical Institute (CAMI), which conducts Aeromedical research; and the FAA's Technical Center, which conducts research on equipment and procedures. The Volpe National Transportation Systems Center (VNTSC) of the Department of Transportation also conducts research for the FAA.

While accidents still may trigger FAA regulatory action and add to the information about what needs to be changed and how, the FAA, even without the impetus of a crash, continually conducts research and contracts to have research conducted to determine technical and procedural improvements that will prevent the loss of lives. An early example of this was the FAA's independent efforts to develop means to provide better traction for aircraft landing on wet runways. While an actual regulation was not issued, the FAA provided guidance to the airport operators in the form of Advisory Circulars (AC).[8] Similarly, the FAA provided advisory information on the methods of design, construction, and maintenance of skid resistant airport runway surfaces. It is interesting to note that this same technology, the grooving of the runway surface to promote removal of standing water, is now a rather common practice on many of the Nation's highways.

Research conducted over the past 10 to 15 years has focused on air traffic control (aircraft separation [TCAS], communications, enroute control, system capacity, etc.; advanced computer programs (advanced traffic management, terminal Air Traffic Control (ATC) automation, etc.); navigation (navigation systems development Microwave Landing System (MLS) displays, instrument approach improvements, and flight crew performance, etc.); weather (advanced windshear sensor developments, weather radar, central weather processing, etc.); aviation medicine (protection and survival, human performance research, etc.); aircraft safety crashworthiness/airworthiness, aging aircraft/flight safety/atmospheric hazards); aviation security

(explosive sabotage detection, etc.); environment (aircraft engine emission reduction, aircraft noise reduction, etc.).

Some research was requested by the various certification offices of the FAA for use in support of proposed safety regulations; for example, windshear regulations, flight crew management training regulations, cabin safety regulations, crashworthiness regulations, aging aircraft continued airworthiness directives, security regulations, etc.

Sometimes, insufficient information or research exists to support a regulatory decision, or the research lags behind the need. For example, research on the effects of aging on pilot performance cannot yet serve as a basis for making a decision on whether to extend the age limit for part 121 pilots. In some instances research data exists but it has not been substantiated by the FAA. A great deal of research has been done on pilot fatigue during long-range flight schedules. But until recently this research has been done by other countries or by academics, not by the FAA or not substantiated by the FAA. In 1985 when the flight time limits in the Federal Aviation Regulations (FAR) were updated after a negotiated rulemaking with industry, the studies were not cited as a basis for the changes. Recently NASA has been conducting additional research for the FAA on pilot fatigue and it is hoped that the cumulative research will support improvements in the flight time limit rules.

Another example of how rules and research work together, or do not work together, is the changes that were intended for the part 67 medical certification rules. Research was conducted for the FAA by the American Medical Association (AMA), which submitted a report on March 26, 1986,[9] that identified needed improvements based on advanced medical technology and new medical information on drug addiction and alcohol addiction. The FAA requested and received comments on the report. Though the research and comments supported regulatory change, and though a draft NPRM was started, changes have not been accomplished, either because of politics, economics, or bureaucratic inertia. If the NPRM is eventually published, much of the research may well be outdated.

Research, rather than accidents should, and often does, drive regulatory change. For example, the Aloha accident with only a single fatality, began the aging aircraft investigation, but since the accident major strides have been made in correcting what had been a hidden but potentially disastrous problem, referred to as multi-site damage (MSD) or widespread fatigue damage (WFD). FAA research, guided by the Technical Center has continued to work on this problem and to define fixes for the problem, both short term inspection fixes and long term structural fixes, that have resulted in numerous airworthiness directives, designed to provide present and short term safety while the tougher long term inspection and structural developments emerge with permanent corrective actions.

Given the current requirement for cost/benefit analyses,[10] initiation and conduct of research is essential if the FAA is to justify the rule changes on a proactive basis. Without justification based on solid research, the FAA would have to wait for loss of more lives in order to posit substantial benefits based on projected lives saved.

The "rope story" illustrates how a seemingly useful idea that had not been researched or tested can prove counter productive. The type certification rules in effect in 1963 required an approved means to assist the occupants in descending to the ground for emergency exits (other than over-the-wing exits) that were more than 6 feet from the ground. Advisory material stated that ropes were acceptable for crew emergency exits. Over-the-wing exits were excepted from the requirement because it was assumed that occupants leaving over-the-wing emergency exits would step out on the wing and make their way easily to the ground. In Notice 63-42, the FAA proposed to require an assisting means at over-the-wing exits stating that it was based on a number of evacuation tests.

While the final rule based on Notice 63-42[11] acknowledged numerous objections to the rope (or other assisting means) requirement, the requirement was adopted and affected aircraft were required to be retrofitted by June 30, 1966. On April 7, 1966 the FAA published a new NPRM (Notice 66-13) proposing to rescind the rope requirement stating the information collected from numerous emergency evacuation demonstrations held during the past year indicated "that use of the required ropes in some cases impedes rapid evacuation rather than speeds it up as intended." Fortunately, before any emergency use of the ropes by passengers in a real emergency, CAMI testing had discovered the error.

The following sections look briefly at instances in which research and regulation have worked together to make it safer.

12. RESEARCH IN SURVIVABILITY.

12.1 EARLY RESEARCH.

In April of 1964, the FAA crash-tested a Douglas DC7 transport aircraft to examine the postcrash causes of fatalities. This test was followed by a crash test of a Lockheed L1649 transport in September. The FAA used this wrecked fuselage in evacuation tests in April of 1965.

These crash tests provided extensive research and regulatory information on postcrash survivability. Over the next three decades, the FAA explored options for reducing evacuation time and preventing postcrash fire, the real killer in otherwise survivable accidents.

Among the many early accomplishments in postcrash survival were the rules requiring that passenger evacuation had to be accomplished in two minutes, using only half the available exits, and the requirement that attendants present a preflight briefing of emergency procedures to passengers.[12]

During the same period the FAA initiated research to prevent two types of postcrash fires. One is the "fireball" which can occur during a crash when released fuel creates a flammable mist in the air that ignites, attaches to the airplane, and creates the ignition source for the pools of fuels in which the airplane comes to rest. The second is a "flash over" condition which occurs when the cabin interior reaches a high enough temperature that the entire inside instantly ignites. To save lives after a crash, the fireball must be prevented, and the airplane interior must remain habitable long

enough to evacuate passengers. Much of the FAA's Research and Development (R&D) has been dedicated to gaining the time by preventing or inhibiting the fires and by faster evacuation procedures.

Research to prevent postcrash fires began in January 1965 when the FAA sponsored an evaluation of jet A and jet B fuels.[13] The evaluation concluded that there were no real flammability differences in the fuels; however, industry suspended the use of Jet B fuels. At the same time, an FAA study concluded that changes in transport fuel tanks could reduce the hazard of postcrash fire. Test results showed that improved design of the fuel tanks resulted in tanks that could tolerate impact loads of 57 g's in contrast to the 40 g's that were considered nonsurvivable.

In 1967, the FAA initiated research to develop safety fuels to reduce postcrash fires and other requirements that addressed improved interior lighting, evacuation slides deployable in 10 seconds or less, improved exit distribution and excess exits, self-extinguishing interior materials, and protection of fuel and electric lines. These changes were coupled with a reduction of the required time for evacuation from 2 minutes to 90 seconds.[14]

In 1970 CAMI pioneered the use of protective smoke hoods but the NPRM proposing to require the use of the hoods was withdrawn because of concerns that the hoods would delay evacuation.

In 1972, new crashworthiness and passenger evacuation standards were added covering seats, safety belts, stowage compartments, cabin interior protection, evacuation procedures, lighting, passenger briefings, and structural design to minimize fuel spillage.[15]

Survivability analysis and testing at CAMI led to the elimination in 1976 of all side-facing attendant seats.[16] The new forward facing seats and seatbelts were intended to protect flight attendants from serious injury during a crash so that they would be able to perform evacuation duties.

Tests at CAMI resulted in FAA regulations in 1977 on the transport of disabled passengers that permitted individual carriers to establish their own procedures. To assist in this process, the FAA prepared an Advisory Circular.[17]

12.2 SAFER ADVISORY COMMITTEE.

In March of 1977, the collision of two B-747's on a foggy runway in Tenerife, Canary Islands, and the fatalities resulting from the fire that engulfed the airplanes further stimulated concerns about preventing postcrash fires.

One result was that in 1978 the FAA established the SAFER Advisory Committee to provide a systematic approach to postcrash problems. At the time, the FAA actually withdrew four NPRMs to allow SAFER to deal with the problem. The notices that were withdrawn dealt with fuel tank explosion prevention, flammability of cabin interior materials, and smoke/toxic gas emissions.

In 1980, the SAFER Committee released its recommendations regarding improved fire safety. It urgently recommended expediting the development and validation of antimisting fuel. The FAA set up working groups to respond to the SAFER recommendations. During the 1980s and into the 1990s many changes in the regulations occurred as a result of crashworthiness research and testing. These changes included fire-blocking interior cabin materials, changes in fuel tanks and fuel systems, changes in seat standards, changes in exits, and the addition of requirements for protective breathing equipment for crews.

12.3 CONTROLLED IMPACT DEMONSTRATION (CID).

A major testing of crashworthiness factors occurred in 1984 when the FAA in conjunction with NASA conducted the Controlled Impact Demonstration of a radio-controlled B-720 airplane. The airplane was fully fueled with antimisting kerosene to test the effectiveness of the fuel in preventing a fireball. The CID did not prove the usefulness of antimisting fuels because in the crash the plane was engulfed in flame. However, the reasons for the fireball may have had little to do with the type of fuel being tried and much to do with errors in the experiment. More recent legislation, namely Public Law 100-591, The Aviation Safety Research Act of 1988, has indicated a continued need for effort to develop low-flammability fuels.

The test did provide information on other safety measures such as the performance of advanced digital flight data recorders, energy-absorbing seats, and fire resistant interior materials. Since the aircraft carried anthropomorphic dummies, the experiment provided CAMI with information on the forces passengers are exposed to in a crash.

12.4 CABIN MATERIALS.

In the 1980s, FAA research showed that the materials used in airplane cabin interiors were a major part of the fire problems. In 1983, SAFER committee investigation into cabin materials technology resulted in a recommendation to apply the fire-blocking concept to aircraft seat cushions as a means of retarding flame spread. Research and tests conducted by the FAA Technical Center which subjected various airline seat cushions to intense and realistic full-scale cabin fire conditions indicated that properly fire-blocked cushions delayed the onset of ignition and reduced the spread of flame and combustion products. NASA research investigated combinations of various fire-blocking materials and polyurethane foams to develop a design technology for adequate fire protection at minimal weight and cost.[18] A rule was issued in 1984.

In 1984, an FAA-contracted study included analysis of fire-related accident/incident data taken over a 10-year period: a survey of available technology and analysis of fire detection, monitoring, and extinguishing options for all areas of a typical wide-body passenger cabin. This included the conceptual design and feasibility analysis of a total cabin integrated fire management system.[19]

In 1986, the FAA issued stricter flammability requirements for cabin sidewalls, ceilings, partitions, storage bins, and other interior materials.[20] Up to this point, flammability standards for cabin interior materials had been that the materials must be self-extinguishing when subjected to a small

flame. The FAA imposed improved standards earlier that were withdrawn in order to have the SAFER Committee study the problem. The SAFER Committee recommended further research and development regarding cabin materials and evaluation and implementation of a test method using radiant heat for screening cabin materials. The FAA concurred with the recommendation and initiated the necessary research and development.[21] The FAA Technical Center, in full-scale fire tests, demonstrated a correlation between flammability and smoke emission characteristics in materials tested.[22] CAMI testing regarding the toxicity of emissions, found a correlation between flammability characteristics and toxic emissions and the severe hazard from toxic emissions occurred as result of flashover fires involving interior materials.[22]

In 1990, the FAA issued an NPRM on improved flammability standards for material used in the interiors of transport category airplane cabins based on FAA Technical Center tests which studied aircraft fire characteristics to develop practical test methods of the materials used in the interiors of airplane cabins.[23] The FAA Technical Center had pioneered the research and established a standard test procedure during which more than 350 candidate materials were examined. The FAA collaborated with the expertise available in the university forum in this endeavor. Once the FAA identified this acceptable procedure in the regulations, industry developed more materials on their own.[24]

The FAA also developed and tested low heat release panels to reduce the rate of flashover. FAA Technical Center tests, using simulated narrow- and wide-body test facilities, showed that use of phenolic/fiberglass material extended the period before flashover by as much as three minutes. This provided a new standard to be used in testing all other materials.

12.5 FUEL TANKS AND FUEL SYSTEMS.

The FAA continued its work on designing fuel tanks and fuel systems that would be less prone to postcrash fire. In a 1984 ANPRM, the FAA discussed the SAFER recommendations. The SAFER Committee had identified and reviewed 15 worldwide transport aircraft accidents since 1964 which involved postcrash fuel tank explosions and were considered impact-survivable. The Committee concluded that in four of the accidents, fuel tank explosions could have been prevented by design changes, but such changes would not have prevented the other explosions. The committee recommended amending the FARs to require: (1) fuel tank vent protection during ground fires; and (2) design practices that maximized the probability of engine fuel supply shutoff in potential fire situations.[21]

The FAA implemented several changes to fuel system standards for general aviation aircraft and transport category helicopters. In 1985, the FAA issued an ANPRM on aircraft engines and engine control systems that was based on 1978 FAA Technical Center tests.[25] The tests showed that fuel system installations with improved crash-resistant bladder cells with crash-resistant flexible hose assemblies and frangible fittings provided improved crash protection in small airplanes. Data from the tests were used by NTSB in formulating recommendations to require the above improvements.

Based on SAFER recommendations an ANPRM was also issued on new standards for fuel tank vent protection for transport category airplanes, shutoff of the engine fuel supply at the fuel tank in the event of a crash landing, and upgrading emergency landing design requirements. This notice also cited a 1978 FAA research program which tested twin-engine airplanes and demonstrated that crash-resistant fuel cells and breakaway fittings could reduce postcrash fires.

In 1985, the FAA required crash-resistant fuel systems in general aviation aircraft of fewer than 10 passengers and in 1990 these were also extended to cover rotorcraft. The rotorcraft rulemaking was based on several reports and studies, including an FAA Technical Center report on an analysis of rotorcraft crash dynamics and an NTSB special study on postcrash fires in general aviation.

In 1989, the FAA issued an ANPRM to determine the feasibility of installing crashworthy fuel tanks and fuel lines which are rupture resistant in all air carrier aircraft. This action was in response to a mandate in the Aviation Safety Research Act of 1988[26], which required the FAA to issue the ANPRM. The ANPRM proposed new standards for fuel tank vent protection for transport category airplanes, shutoff of the engine fuel supply at the fuel tank in the event of a crash landing, and upgrading emergency landing design requirements.[27]

12.6 PROTECTIVE BREATHING EQUIPMENT (PBE).

PBE was required in transport aircraft that have cargo compartments which the flight crew may enter during flight under the certification requirements of Part 25. In Paris during July 1973, a Boeing 707 airplane force-landed short of the runway as a result of a cabin fire started in a rear lavatory waste bin. Only 11 of the 134 occupants survived the landing. Revised PBE standards could have allowed the flight attendants to extinguish the fire. In 1987, the FAA issued rules requiring protective breathing equipment for Part 121 air carriers and commercial operators who operate aircraft having a passenger seating configuration of more than 30 seats.[28] This was a retrofit rule and updating of PBE standards. The rulemaking was in response to accidents and NTSB recommendations and was based on an FAA conducted survey of reports concerning human physiological limitations from 15-minute exposures to contaminants likely to be present in aircraft fires. Results of the survey showed that acceptable levels of contaminant concentrations in the air for 15 minutes of exposure were 5 percent for breathing and 10 percent for eye contact. Using these concentration levels FAA tested a number of oxygen mask—smoke goggle combinations. The tests showed that many permitted more than the acceptable concentration levels. These standards were subsequently incorporated into Technical Standard Order (TSO)c99. The rule incorporated Part 25 PBE requirements into Part 121; requested that Part 121 conduct fire drills using PBE and the PBE TSO; required that PBE allow for an inter phone between the cockpit and the flight attendants; and requested additional PBE's depending on the number of passengers. In 1992 PBE training was proposed for Part 121 crew members[29] and in 1993 the FAA proposed to modify the standards for PBE.[30]

12.7 SEAT STANDARDS.

Based on research testing and service experience, the FAA issued a proposal in 1986 to improve safety standards.[31] The proposed standards upgraded occupant protection during emergency landing conditions by increasing the capability of the seat and restraint system to absorb a crash impact and by providing protection for the items of mass that may come loose during impact. One of the research studies was the result of an FAA/NASA contract with airplane manufacturers to review and evaluate transport airplane accident data and define areas where passenger safely could be improved on transport airplanes in survivable accidents. The findings were detailed in a series of reports.[32] The FAA Technical Center and CAMI also developed a report on crash injury protection between 1970-1978. The report compiled a data base on passenger seat and restraint system performance in survivable accidents and determined if a correlation existed among occupant, seat, and restraint system performance, airframe and floor deformation, and passenger injuries and fatalities. The standards were also based on the findings of the FAA and NASA CID. The result of the various studies and tests was the development of improved dynamic test standards for transport category airplanes. With these standards in hand, in 1988 the FAA issued rules requiring a retrofit of improved seats in air carrier transport category airplanes.[33]

The revision to the standards basically replaced the theory that stronger seats are better with the findings that energy absorbing seat structures allow the seat and its attachments to deflect within limits and thereby transmit a lesser force to the occupant.

12.8 EXITS AND PATH MARKING.

In 1983, the FAA required emergency escape path marking on the floor of transport category airplanes.[34] The requirement was based on a SAFER Committee recommendation which in turn was based on accident experience showing that smoke from burning fuel and cabin material can obscure overhead emergency lighting and make cabin evacuation difficult and that floor lighting and marking where the air is clearer would help in evacuation.

In 1987, a rulemaking that updated the location of emergency exits in transport category airplanes was based on CAMI tests.[35] The tests, conducted in the emergency evacuation simulator, demonstrated that passengers have difficulty traversing an aisle located between passenger seats in a cabin inclined because of landing gear collapse.

In 1990, the FAA required that persons seated in emergency row seats must be capable of opening emergency exits.[36] This rulemaking was based on CAMI research which assessed the effects of handicapped passengers aboard aircraft during an emergency evacuation. The rulemaking was also supported by a study done by the Office of Aviation Medicine which found that passenger survival depends upon the ability of uninjured passengers to make their way to an exit within the time limits imposed by the thermotoxic environment.[36]

In 1990, the FAA proposed additional exit sizes for transport category airplanes to improve the efficiency of passenger egress in an emergency evacuation. This requirement was based on CAMI

tests of passenger evacuation rates with exit door widths of 26 to 42 inches.[37] Similarly, in 1992, the FAA required improved access to Type III exits. This requirement was based on CAMI tests evaluating the ease with which exits can be opened and the effect of passageway width on flow through them.[38]

12.9 CHILD RESTRAINTS.

After incidents in which children were injured by unexpected turbulence and the accident at Sioux City, Iowa, the FAA initiated rulemaking to allow the use of approved child restraint systems. It is important to note that the FAA did not require the use of the restraint systems. The FAA postulated that if the use was made mandatory, the cost to the parents of a seat on the aircraft for the child could become a deciding factor in their choice of transport by automobile or air. The fatality rate of children under the age of 2 might have been increased if the choice of automobile travel over air was inadvertently encouraged.

The rule was based on CAMI research and research conducted by the Arvin/Calspan Advanced Center for the FAA which showed that the use of child restraint systems provides children with an increased chance of surviving accidents. The research also recommended the types of child restraints that should be approved for use in aircraft.[39] Most recently however, CAMI research has resulted in another rule change. The research shows that approved National Highway Transportation Safety Administration (NHSTA) child restraints are not entirely acceptable for air travel. Some of these restraints, given the type of accidents and incidents that can occur in air travel, could cause the child to be crushed or to hit the seat back in front. This research has led to a spot amendment to the regulations to quickly disqualify some child restraints for use in airline travel that are approved for use in automobiles.[40]

13. RESEARCH IN PREVENTION OF ACCIDENTS.

Other rulemaking which have definitely been supported by research have focused on the prevention of accidents. Inflight fire prevention has resulted from research supported rules which require certain materials for lining cargo compartments, improved regulations on fire extinguishers, and no smoking rules.

Research has supported rulemaking that requires adding equipment to airplanes such as Cockpit Voice Recorders and Flight Data Recorders that will provide vital information to help prevent future accidents. Windshear equipment and training are now required for Part 121 and Part 135 operations; these requirements were supported by research. Requirements for crew resource management training are being added to the training regulations. While many of the problems that these rulemakings are intended to prevent were first identified as causes of accidents, research and tests conducted by or for the FAA have been instrumental in shaping the rules and in supporting the need for each rule.

13.1 COCKPIT VOICE RECORDERS (CVR) AND FLIGHT DATA RECORDERS (FDR).

When an accident has occurred, the accident investigation attempts to determine the causes of the accident so that the same type of accident can be prevented from happening again. Part of the accident investigation relies on what occurred in the cockpit just before the accident, as recorded on the CVR, and what the flight characteristics of the airplane were, as recorded on the FDR. In March 1967, the FAA required that all turbojet and four-engined piston powered aircraft have CVRs installed.[41] In 1969, the FAA required that large transport aircraft have advanced FDRs.[42] In 1970, the CVR requirements were extended to large transport category aircraft operating in scheduled service.[43]

In 1983, Trans System Corporation did a study entitled "Cockpit Voice and Flight Data Recorder Evaluations" for the FAA that examined various CVR and FDR equipment requirement options; the study also estimated the number of new airplanes manufactured that would be subject to the new rule. The study was cited in a proposed rule to update CVR and FDR equipment requirements.[44] In 1987, the Final Rule required improved digital flight data recorders for older, larger Part 121 aircraft certified through September 1969, and CVRs in all newly manufactured multi-engined, turbine-powered aircraft certified under Part 135 that carry more than six passengers.[45]

13.2 GROUND PROXIMITY WARNING SYSTEMS.

In September 1968, the FAA issued rules requiring an altitude alerting system for all civil turbojet aircraft by February 1972.[46] The purpose of the alerting system was to warn pilots if a plane was too low and therefore at risk of colliding with terrain or obstacles. In 1974, a TransWorld Airlines airplane crashed into a mountain in West Virginia during its approach to Dulles International Airport. The cause of the accident was either unclear approach charts or a misinterpretation on the part of the pilot of the air traffic controller's message. The accident led the FAA to issue a rule requiring all large aircraft to have Ground Proximity Warning Systems (GPWS) by December 1975.[47]

In 1992, in a rule requiring GPWS for all turbine-powered (rather than just turbojet) airplanes with 10 or more seats operating under Part 135, the FAA cited two studies conducted on flight into terrain.[48] One study, conducted for the FAA, reviewed Controlled Flight Into Terrain (CFIT) reports from 1976 through 1980 and found that GPWS and Minimum Safe Altitude Warning Systems were the initial recovery factor in 18 serious incidents and the sole warning in 6 reported instances which otherwise would have probably ended in disaster. At the request of the FAA a VNTSC study investigated 27 CFIT accidents between 1977 and 1988 involving turbine-powered airplanes operating under Part 135 and found that 66 percent of the accidents could have been prevented if the airplanes had been equipped with GPWS.[49]

13.3 WINDSHEAR EQUIPMENT.

From 1964 to 1983, 28 transport category airplane accidents occurred during takeoff or approach and landing which were at least partly attributed to windshear. Since then ground radar

equipment which can identify areas of windshear and windshear equipment for airplanes have been developed.

In 1979, the FAA issued an ANPRM requesting comments on ground radar windshear protection equipment, airborne low-altitude windshear equipment, and the training requirements.

In 1982, an accident attributed to a microburst-induced windshear at New Orleans International Airport caused the U.S. Congress and the FAA to focus on the need for development of an integrated windshear research and development program to address all aspects of the problem. In 1986, the FAA circulated a draft Integrated Windshear Program plan, featuring improved ground-based detectors, Next-Generation Radar, airborne sensors, and a terminal Doppler weather radar. Also in 1986, the FAA announced a cooperative effort with NASA to develop basic requirements for an airborne windshear detection and avoidance system that would "look ahead" of the aircraft rather than react when the windshear was encountered.

In 1987, the FAA issued a subsequent Notice of Proposed Rulemaking[50] identifying the research that had been conducted and was being used to support windshear protection. The notice identified several major research projects:

a. In December 1982, Congress passed Public Law 97-369 requiring the FAA to contract with the National Academy of Sciences (NAS) to study alternative approaches of windshear alert standards.[51]

b. In 1977, the FAA conducted a study of NTSB reports on aircraft accidents and incidents related to low-altitude windshear from 1964 through 1975. The study showed that of the 25 windshear accidents and incidents, 23 occurred during approach or landing and two during takeoff.

c. In 1984 and 1985, the FAA sponsored research in testing Doppler Locator radar's operational use at airports.

d. Before issuing the ANPRM in 1979, the FAA conducted a series of simulator experiments to investigate the effectiveness of low-altitude windshear systems designed to warn pilots of the existence of windshear and assist them in transiting or avoiding the windshear.

e. The FAA conducted a series of flight simulator tests over a 4-year period to determine the most effective way to manage windshear penetrations. The FAA developed a set of standard low-altitude windshear profile models to use in the tests.

f. The FAA contracted with a consortium of specialists to produce windshear training documents and videos.

In 1988, the FAA issued a rule requiring additional equipment to warn pilots when low-altitude windshear was expected and to provide the flight guidance for a missed approach. It also

required the airlines to provide windshear ground training in simulators for flight crew members.[52]

In 1989, the FAA proposed to modify amendment 79-11A to exempt older airplanes, extend compliance time, and accept alternatives to the equipment requirement. The proposal was in response to Air Transport Association studies submitted to the FAA which found that the use of windshear guidance equipment in older airplanes would not be more effective than existing windshear technology (Windshear Training Aid). These studies were used in a petition which called for the FAA to repeal the requirement that older airplanes be retrofitted with the flight system. Also in 1989, a report from the Office of Technology Assessment, entitled "Safer Skies with TCAS" noted that uniform attainment of the TCAS II phased retrofit schedule coupled with the phased retrofit schedule for windshear equipment would be difficult to achieve.

13.4 DEICING PROCEDURES.

Another rulemaking of significance to safety associated with bad weather is the deicing rulemaking. Again, accidents caused at least in part by icing on airplane wings triggered the research on and development of safer procedures under icing conditions.

In 1974, a Northwest Airlines airplane crashed as a result of icing of the pitot sensor heads, giving the pilot erroneous altitude and flight speed information, prompting the FAA to issue a rule requiring a pitot heat indicating system.[53] In 1982, an Air Florida accident in a snowstorm at Washington's National Airport prompted the FAA and industry to implement action to improve the awareness of cold and inclement weather operations. In 1991, as a result of a Scandinavian Airlines accident caused in part by icing, the FAA issued Airworthiness Directives requiring visual detection aids for the wings of specific aircraft types.

In 1992, the FAA issued a regulation requiring Part 121 certificate holders to have a deicing/anti-icing program in place by November 1992.[54] A similar rule affecting Parts 125 and 135 was issued in 1993.[55] The rulemaking was based on FAA research and development on aircraft icing characterization, protection concepts, and deicing/anti-icing fluids and on the recommendations of a task force.

13.5 FIRES ON AIRPLANES IN FLIGHT.

Fires that originate in an airplane cabin or in a cargo compartment during flight can cause injuries and accidents. The FAA initiated changes to the rules with the support of research to prevent such fires from occurring and getting out of hand.

In 1973, a lavatory fire aboard a Varig Airlines airplane started the FAA initiative toward the no smoking rule on transport aircraft. In 1983, an Air Canada accident, resulting in 22 fatalities, at Greater Cincinnati International Airport in which the seriousness of a lavatory fire was underestimated by the flight crew added urgency to the FAA's efforts to eliminate cabin fire deaths. Coupled with the SAFER Committee recommendations and subsequent FAA research

and development of fire-blocking seat and wall materials, rules were issued in October, 1984 (as discussed under "survivability").

In 1984, the FAA proposed cabin fire protection requirements including smoke detectors for each lavatory and galley, automatic fire extinguishers for lavatory trash receptacles, and an increase in the number of hand-held fire extinguishers for more than 60 passenger aircraft, two of which must be charged with Halon 1211 extinguishing agent. Specific requirements were based on an FAA-contracted study which included analysis of fire-related accident/incident data taken over a 10-year period and analysis of fire detection, monitoring, and extinguishing options for all areas of a typical wide-body passenger aircraft.[19] The FAA also conducted cabin fire extinguisher tests using various types of hand extinguishers and agents. Results indicated the effectiveness of the Halon 1211 agent extinguishers.[56]

In 1985, the FAA issued the final rule to improve major airlines cabin fire protection for passengers which addressed lavatory smoke detector and trash container automatic extinguishers, along with increasing the number of hand-operated extinguishers for the cabin.[57]

Cargo compartment fires are another source of inflight fires. Typically cargo fires are controlled by oxygen starvation. Even if a fire breaks out in a cargo compartment the lining will usually contain the fire and it will extinguish before any damage is serious enough to cause an accident. Testing at the FAA Technical Center led to an NPRM in 1984 proposing to upgrade fire safety standards for cargo or baggage compartments by establishing new fire test criteria and also limited the volume of class D compartments.[58]

The Technical Center tests, conducted using simulated class C and D compartments, investigated liner materials. In conjunction with the tests, the FAA developed a method of testing liner materials. The tests also showed that the intensity of a fire in a large class D compartment was greater because of the total amount of oxygen available in compartments larger than 1,000 cubic feet. In May of 1986 the FAA upgraded fire safety standards for cargo or baggage compartments by establishing new fire test requirements.[59]

In 1989, the FAA issued fire protection requirements for cargo or baggage compartments based on FAA Technical Center tests which investigated the capability of three liner materials to resist flame penetration under conditions representative of actual cargo or baggage compartment fires.[60] These tests found that a fire could rapidly burn through liners constructed of Kevlar™ or Nomex™. The tests led to new type certification standards for class C or D cargo or baggage compartments in transport category airplanes.

13.6 BIRD INGESTION.

Operational experience plays a large part in the changes. Of specific note is the FAA certification requirements for withstanding ingestion of foreign objects or materials. Prime examples of such objects are birds. FAA Part 33 has requirements that the engine manufacturer must demonstrate by test that the engines can ingest birds of various sizes and numbers without significant or hazardous loss of thrust. In 1980, the FAA proposed to industry that the sizes and numbers of

birds to be used in the certification testing be increased. Industry response to this proposal stated that there was no service experience that would justify this proposal.

FAA then initiated multiple-year, worldwide surveys of the bird ingestion populations to determine what, if any, changes to the requirements should be made.[61] The surveys were conducted by the manufacturers of the engines affected, under contract to the FAA, and the analysis of the results were also done under contract (with guidance from the FAA Technical Center) by The University of Dayton Research Center.[62] Because this involved real-time data collection, the process to provide the supporting information is lengthy; the FAA's formulation of the rule revision is currently being reviewed with industry. A cautionary note about issuance of this type of rule to combat a hazard; the intent is to attempt to prevent the ingestion by avoiding known areas of bird activity and by improving the engine's durability. However, it will not eliminate the single or "rogue" bird event—birds just do not respond to a written rule!

13.7 UNCONTAINED ENGINE ROTOR FAILURE.

Transport category aircraft are certified under Part 33 to provide protection to the critical flight components against the inadvertent uncontained failure of engine compressor or turbine discs or blades. With the increasing passenger traffic using rotorcraft, the FAA has taken steps to ensure that the safety provided to these passengers is equivalent to that historically provided to those using fixed wing transport. The FAA has realized that Parts 27 and 29 which govern the rotorcraft categories are not required to demonstrate the same protection against the uncommon but possible noncontainment of failed engine parts.

In 1989, The FAA issued an NPRM to require that manufacturers consider the safety implications of a failure of an engine rotor disc and to implement practical design precautions to minimize the hazard to rotorcraft.[63] The comment period for this notice was extended to clarify the FAA position regarding redesign or use of other means of compliance. The FAA Technical Center at the request of its Rotorcraft Directorate researched the probabilities of critical components of Part 27 or 29 rotorcraft being struck by rotorburst segments or blades.[64]

Simultaneously, the Technical Center let research contracts to foster the development of light weight penetration-resistant materials capable of providing the desired protection. [65,66,67,68,69,70]

13.8 AGING AIRCRAFT.

In April of 1988, an Aloha aircraft while at cruise speed experienced an inflight structural failure of the forward upper portion of the passenger cabin and the subsequent loss of a flight attendant.[71] The aircraft was skillfully brought to a safe landing with no further fatalities or injuries but the degree of damage that was evidenced opened an unknown and unexpected failure mode. Very small fatigue cracks had developed, initiating under the heads of the riveted fuselage skin. These cracks, almost undetectable, were found at adjacent rivets to have joined up, exceeding the residual strength of the structure. This type of structural failure, coined MSD, triggered the FAA to have other aircraft operating in similar fashion inspected, with the result that

the same type of damage was in fact present. The FAA immediately issued Airworthiness Directives requiring inspection and repair of aircraft affected by this problem. It was found that the cracking was not limited to just one class of aircraft, but was present throughout others classes; the key being connected to the flight time and flight cycles each aircraft had experienced.

With industry's concurrence and cooperation, the FAA established the Aging Aircraft Research Program. This spanned technology areas of fatigue/fracture, corrosion, maintenance, nondestructive inspection, flight loads and human factors. The FAA, in the process of solving the riddles of MSD and its relationship to the other technology areas, established Centers of Excellence to concentrate the knowledge and expertise of industry, academia, and government.

One of these centers, the Center for Aviation Systems Reliability (CASR), located at Iowa State University is charged with research in the development of inspection techniques; another is the Aging Aircraft Nondestructive Inspection Validation Center (AANC), located at Sandia National Laboratories to perform validation and technology transfer of the developed inspection techniques to the industry; the FAA is utilizing the Carnegie-Mellon Research Institute to apply robotics technology to the inspection systems; the task of analyzing and developing methodologies to combat MSD is being addressed jointly by the FAA, Boeing, and McDonnell-Douglas.

13.9 AIRWORTHINESS DIRECTIVE ISSUANCE.

Industry actions to effect changes in their products for more efficient manufacturing, improved durability or performance, or because of failure (or incipient failure) are usually accomplished by the issuance of service bulletins. These bulletins are continually monitored by the FAA personnel (Principal Maintenance Inspectors, primarily) to assess whether safety is involved.

Manufacturers maintain product support groups who continually monitor and track their company's products no matter how many times it may change ownership and location. As such, there is a constant feedback to the original manufacturer about operational performance. These groups are often responsible for providing the information to the manufacturer that prompts the issuance of service bulletins, or more importantly, of alert bulletins, usually a sign the industry feels safety is involved. Usually when such is the case, the Principal Maintenance Inspector (PMI) will convert the bulletin into an Airworthiness Directive (AD), which carries mandatory corrective actions.

Independent AD action by the FAA most likely occurs as the result of an accident or an incident of significant seriousness. In the case of the Aloha accident, the FAA used the AD vehicle in a widespread fashion to assure that the full magnitude of the problem was covered and understood by the industry and the public. In cases such as this, the FAA basically adopts the premise "what if?" and takes the conservative approach to assure that related failures are not overlooked. In many cases, ADs eventually result in the development of an AC which addresses the subject of the problem and all related possibilities. The release of an AC has a more long lasting effect on safety since it covers a more wide area than the specific failure that spawned it and is usually cited in related rules. In this manner, issuance of ADs can be looked upon as "preventative medicine" to the industry.

Over the period 1973 to 1991, the FAA issued 4342 Airworthiness Directives. Of this total, 1988 were issued against general aviation aircraft, 884 were issued against commuters, and 1470 were issued against the large transport category aircraft. During this time, there was a gradual increase in the numbers of ADs for the large transport category aircraft, but a marked increase occurred in the 1988 through 1991 period. This jump in AD activity is attributed to the Aloha accident in April of 1988. The commuter fleet also exhibited a gradual increase which probably reflects the increase in commuter travel associated with deregulation. Interestingly, the commuter trend would parallel the large transport trend were it not for the impact of the Aloha accident activity.

13.10 BENEFIT/COST PROJECTED AS A RESULT OF AIRCRAFT SAFETY REGULATORY PROPOSALS.

Since the early 1980s, the FAA, in compliance with Executive Order 12291 of February 17, 1981, instituted a practice of providing benefit-cost analyses information whenever a rulemaking was proposed. The practice was intended to provide justification of the costs involved in the proposed regulatory action. In general, the benefits that were to be gained to balance the cost of the action were stated, usually equated to the number of lives to be saved by the action, the number of serious and minor injuries to be avoided, and the monetary value of the aircraft hulls saved.

The following tabulation of proposed regulatory actions from the early 1980s to the present shows quite clearly that actions to prevent the occurrence of postcrash fires, or to provide means of escaping the aircraft when fire is either present or imminent result in the best ratios relative to fatalities. In most of these instances, the data that is cited to support the action was derived from research and development activities. In many of the cases, this work was accomplished at either the FAA Technical Center or CAMI.

			Projected Savings	
Regulatory Action	**Date**	**Subject Matter**	**Lives**	**Injuries**
NPRM 8-15	10/11/83	Emergency Floor Lights	10.2/yr.	—
NPRM 85-11	5/6/85	Shoulder Harnesses	—	42/yr.
NPRM 86-19	12/12/86	Part 23 Cabin Safety	1.7-5.0/yr.	—
NPRM 87-3u	NPRM 87-3u	Low Fuel Alert System	Benefit is in future accident avoidance	
NPRM 87-10	10/20/87	Exit Distances	1.4/yr.	—
NPRM 88-5	3/16/88	Decompression Control	10.8/yr.	—
NPRM 89-1	1/12/89	Smoke Detectors	14.4/yr.	—
NPRM 89-8	3/13/89	Handicapped Seating	Undefined, but substantial	
NPRM 89-23	9/8/89	Evacuation Requirements	1.0/yr. (max)	4.0/yr. (min)
NPRM 90-4	2/13/90	Improved Exits/Slides	6.4/yr.	—
NPRM 90-6	2/22/90	Child Restraints, etc.	0.33/yr.	0.30/yr.
NPRM 91-1	4/4/91	Improved Type III Exits	1.6/yr.	—
NPRM 93-71	7/14/93	Commuter Seat Upgrade	1.1/yr.	5.3/yr.

14. CONCLUSION.

This foregoing survey of 30 years of FAA rulemaking indicates that research has contributed to substantial improvements in aviation safety. The number of air transportation deaths has decreased at the same time that the number of passenger enplanements has greatly increased. Thus, while it may seem that aviation rulemaking and the research that supports it are moving too slowly to keep up with the need, a 30-year retrospective shows how many significant risks in aviation transportation have been reduced—cabin fires, windshear, collisions into mountains, and others. As long as risk exists, research will be needed to determine the most effective means of reducing or eliminating that risk. The future holds many challenges, not the least of which is the growth air transportation to meet the needs of a growing population and to make aviation ever safer as it grows.

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4. NPRM 93-9, Fatigue Evaluation of Structure (58 FR 38642, July 19, 1993).

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35. NPRM No. 87-10 (52 FR 39190) October 20, 1987.

36. Amendment 121-124, February 28, 1990, based on NPRM 89-8.

37. NPRM No. 90-4 (55 FR 6344) February 22, 1990.

38. Amendment 25-76, April 28, 1992, based on NPRM 91-11; Report No. DOT/FAA/AM-89/114, The Influence of Adjacent Seating Configuration on Egress Through a Type III Emergency Exit.

39. Amendment 91-231, September 8, 1992, based on NPRM 90-6.

40. Amendment to be issued in September 1994.

41. Amendment 121-23, December 3, 1966.

42. Amendment 25-25 and 121-66, August 19, 1970, based on NPRM 69-3.

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